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Defragmentation, Thermocapillary Extraction and Agglomeration of Ultradispersed Inclusions of Noble Metals in Laser Processing

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Thermal-physics and hydrodynamic processes are analyzed that appear in laser processing in mineral raw materials and technogenic products with ultradispersed inclusions of noble metals. It is established that laser processing of these materials is accompanied by the processes of defragmentation, thermocapillary extraction, and agglomeration of micro- and nano inclusions of noble metals.

Keywords: Laser processing, Defragmentation, Thermocapillary mechanism, Laser agglomeration.

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1. INTRODUCTION

Applied to extraction noble metals and platinoides (NMaPs) is further aggravated by the fact as the complexity of the morphology and the chemical structure of such inclusions [1-3]. Feature of laser processing , as well as the use of microwave-, electric pulse, magnetic pulse, electrochemical machining, electrodynamic and shock- wave effects [1] suggests a complex, one technological approach, the implementation of defragmentation source of minerals. However, a distinctive feature of laser processing becomes action of the thermocapillary mechanism of extraction and laser sintering, which are initiated as under pulsed and continuous laser treatment with mineral assemblages and man-made structures in which revealed the formation of visible microformations sizes up to several hundreds of microns [4-6].

2. PHYSICAL QUALITY MODEL

When laser radiation (LR) impacts heterogeneous and heterophase media (HPM) in the form of mineral raw materials and technogenic products with ultra- and nanodispersed inclusions of NMaPs, thermal processes are initiating and dominant processes follows Bouguer-Lambert-Beer's law: $I(z) = I_0(1 - R)\exp(-\alpha z)$.

In contrast to the [6] for simple assessed predictions of the LR intensity absorbed in HPM one can use the averaged value of the absorption coefficient $\alpha = k_1\alpha_1 + k_2\alpha_2 + \ldots + k_n\alpha$, where α_1, α_2, …, α_n and k_1, k_2,…k_n are absorption and concentration of each of mineral phases determined by X-ray phase analysis (XPA). The fact that LR is monochromatic justifies analysis with respect to the averaged magnitude α. The absorbed LR energy causes heating, defragmentation, melting, evaporation, combustion, thermal oxidation, ionization, and plasma formation and also secondary effects such as laser-induced break-down, absorption of radiation by plasma and mechanical deformation. After the termination of LR crystallization occurs.

To evaluate the role and effect of each of physical parameters (specific heat – c, melting heat – λ, evaporation heat – L, coefficients of thermal diffusivity – χ and heat transfer – η, and other characteristics of processes that occur in laser processing), in analogy to α, we propose to normalize their contribution according to mass. For example, smallness of the magnitude of χ (10^{-6}-10^{-7} m^2/c) is responsible for the balance of occurring processes. The generalized scheme that illustrates thermal processes at processing with LR intensity I_0 is given in Fig. 1. Heat balance equation with respect to averaged physical parameters c, λ, L and η is

$$Q_{\text{las source.}} = cm\Delta T + \lambda m_{\text{mel.}} + Lm_{\text{evap.}} + \eta\pi d(T_{\text{mel.}} - T_{\text{min mel.}}), \quad (1),$$

where m is the total mass of HPM, $m_{\text{evap.}}$ and $m_{\text{mel.}}$ are mass of evaporated and melted HPM, d is the diameter of the focusing spot. Here $T_{\text{melt.}} = (T_{\text{1melt.}} + T_{\text{2melt.}} + \ldots + T_{\text{nmelt.}})/n$ is the averaged melting temperature, and the magnitude $T_{\text{min melt.}} - \min\{T_{\text{пл.}}\}$ is the lowest from the melting temperatures for HPM, analogy [6].

Defragmentation (disintegration) processed compositions LR plays the role of a highly efficient source of heat, which is incorporated under the influence of a complex of channels for the dissipation of heat energy, which provide the feasibility of thermal balance (2). We carry out the analysis, writing in the following form:

$$I_0A = Kv_{\text{mel.}}\,\rho(L_{\text{evap.}} + L_{\text{mel.}} + c(T_{\text{mel.}} - T_{\text{min.mel.}})), \quad (2)$$

where I_0 is the density of power (intensity) of LR, L_{evap} is the evaporation heat, $L_{\text{mel.}}$ is the melting heat and A is its absorption coefficient. From this equation it can be calculated optimum value of the speed of the laser beam, the processing time and the diameter of the focal spot. This attests that pulsed laser processing (with durations of up to hundredths of microseconds) is practical and economically sound.

Thus, in laser processing there is always sequence of the above processes, namely, defragmentation (disintegration), extraction of ultra- and nanodispersed gold, and laser agglomeration. Agglomeration, the so called coalescence, makes it self-evident as the end result of the action of surface tension gradient when the motion of dispersed and ultradispersed gold particles to the surface of melt is accompanied by their uniform agglomeration up to the formation of visible thin foil.

In this paper, based on research findings developed

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and proposed for practical use automated installation, based on the application for allocation LR nano- and ultrafine NMaPs inclusions of minerals, and industrial products. It in a single cycle laser processing complex problems are solved:

– complete defragmentation of the starting materials;

– high-level extraction, based on a newly installed thermocapillary mechanism;

– the agglomeration of noble inclusions.

The proposed complex equipment is automatic feed rates and moving products processing, as well as the intensity of LR. It is the integrated use of automatic control process provides complete defragmentation of the original mineral or industrial products and by the actions of the newly opened, thermocapillary mechanism, a high-level (up to 90 %) recovery mineral concretions s and agglomeration of nano-and ultrafine noble inclusions.

As a result, the laser processing products gain size over 20 mm, which is sufficient for detection NMaPs and their separation by gravity methods. Automatic control is ensured by feedback. The optimal intensity of the source LR, its mode of operation, the feed rate of processing the substrate product and its rate of movement in the area of laser exposure depend on the level of the most complete remelting of starting materials as measured by the brightness of the digital image recorded by the transverse profiles of scattered radiation. For this purpose, the apparatus consisting of a laser source, the hopper of the dispenser, collar precursors poured onto the conveyor belt having a graphite substrate in the form of cylindrical troughs (shown Fig. 1 has a digital camera with a slit collimator and feedback device connected a personal computer).

According to Fig. 1 set of equipment includes a laser source – 1 bunker – 2 dispenser – 3, starting products – 4, the graphite substrate with cylindrical gutter – 5, slit collimator – 6, CCD- camera – 7, the feedback device with a PC – 8. device operates in a pulsed mode or a periodic pulse (with a pulse width of not less than 10 microseconds with an energy of 1 *J*) or continuously (with a capacity of not less than 100 W) to generate the near-infrared range (with a wavelength of about 1 micron).

After the installation and the process is carried out as follows. Mineral raw materials and technological products – 1 – starting material (Fig. 1) containing ultra – ionic and colloidal NMaPs switching for processing LR served (with velocity V_c) from the bunker - with dispenser 2-3 (or manually) and uniformly form the shoulder – 4 with dimensions of 8 mm × 6 mm on a substrate made of graphite – 5, having the entire length of the cylindrical trough – 5 (Fig. 1). The test compounds undergo laser treatment as falling – $I_0\lambda$, and reflected radiation – I_0.

The intensity – I_0 and wavelength – λ source *LR*, its modes of operation – 10, the feed rate – V_c treatment products on the substrate through the dispenser – 11 and the speed of the cell – V_p – 12 are selected , either automatically by the signal – 9 with a CCD- camera – 7 with feedback devices – 8 and the operator's PC – 13, or manually. The main element that sets the control parameters (10-12) , serves as a CCD- camera – 7 with a slit collimator – 6 , oriented perpendicular to the cross section of the cylindrical trough in the field of laser exposure. Digital images recorded transverse sections – 9 scattered LR – reflected radiation possible to determine the level of the most complete product processing and refining to make with the help of the feedback device – 8 appropriate corrective changes in control parameters (10-12) of the plant, either automatically or manually.

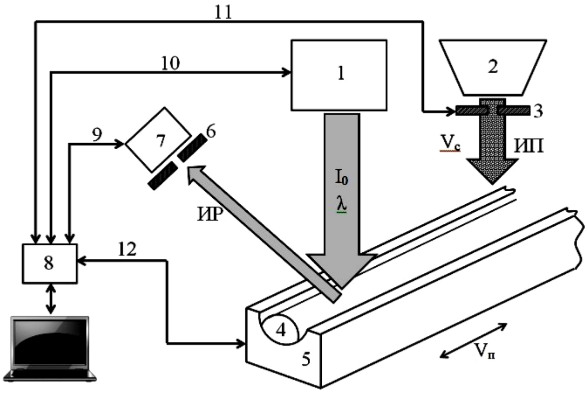

Fig. 1 – Block-diagram of the apparatus for the separation of ultrafine-ionic and colloidal noble inclusions of minerals, and industrial products

Implementation of the proposed plant and method allows to solve these problems: deep defragmentation initial phase inclusions by gradual melting (without evaporation), thermocapillary isolation and the agglomeration of noble inclusions.

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